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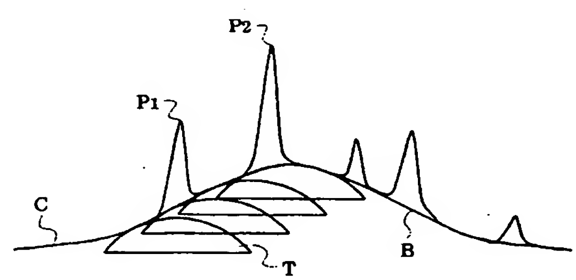
(54) Determining a base line of a measurement curve.

(57) A base line (B) of a measurement curve (C) is determined by preparing a template (T) having an upwardly convex arc; moving, without rotating, the template (T) with the arc of the template always contacting the measurement curve (C); and determining the base line (B) as the envelope of the arc of the template (T).

Fig. 1



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This invention relates to determining a base line of a measurement curve, for example a data curve recorded by a measurement.

When data from a measurement apparatus, such as a chromatograph or spectrometer, is continuously plotted against time, wavelength, etc., a measurement curve including a peak or peaks is obtained. Due to various factors, the base line of a measurement curve often deviates from a zero line of the measurement apparatus or recorder. In this event, it is necessary to determine the base line first to measure the true height (or to measure the area) of the peak or peaks. Determining the base line is especially difficult when, as shown in Fig. 1 of the accompanying drawings, the base line B of a measurement curve C (on which a peak or peaks P1, P2 stand) curves.

A previously proposed method of determining a base line is as follows. First, a peak is detected by detecting the rising point and the falling point at which the absolute value of the slope of the measurement curve becomes greater than a certain reference value and becomes less than another reference value. The starting point of the peak is determined as the point which is a preset distance before the rising point, and the ending point of the peak is determined as the point which is a preset distance after the falling point. The base line in this case is determined as the line connecting the starting point and the ending point.

There are several other methods of determining the base line of a peak, but, in any case, the starting point and the ending point of a peak should be determined first. In order to determine these points, the operator must determine beforehand various parameters, such as reference values for the slope of the rising point and of the falling point or the values of the preset distances. If the parameters are once determined, then the base line can be determined automatically. But, many operators find difficulty in determining appropriate values for the various parameters because the values are not apparent from the measurement curve.

According to a first aspect of the invention there is provided a method of determining a base line of a measurement curve, the method comprising the steps of:

preparing a template having an upwardly convex arc;

moving, without rotating, the template with the arc of the template always contacting the measurement curve; and

determining the base line as the envelope of the arc of the template.

According to a second aspect of the invention there is provided a data processing apparatus for determining a base line of a measurement curve, the apparatus comprising:

measurement curve generating means;

template generating means for generating a template having an upwardly convex arc;

moving means for moving, without rotating, the template so that the arc of the template always contacts the measurement curve; and

envelope generating means for generating an envelope curve of the arc of the template while the template is moved, whereby the envelope is the base line of the measurement curve.

The method and apparatus alleviate the operator's burden in determining the base line of a measurement curve, and provide an easier way of determining the base line. That is, since the operator can prepare (or determine the shape of) the template having regard to the measurement curve, and the determination of the shape of the template need not be so strict, the operator's burden is greatly alleviated.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Fig. 1 is a diagram showing a template moved while contacting a measurement curve;

Fig. 2 shows a presentation of a display device of apparatus embodying the invention;

Fig. 3 is a flowchart of a base line determining method embodying the invention;

Fig. 4 is a block diagram of data processing apparatus for determining a base line of a measurement curve by a technique embodying the invention;

Fig. 5 is a block diagram of a data analyzer embodying the invention;

Fig. 6 is a flowchart of a program performed by the data analyzer;

Fig. 7 is a flowchart of a subroutine of the program Fig. 6;

Fig. 8 is a flowchart of another subroutine of the program of Fig. 6; and

Fig. 9 is a graph for explaining the geometry of the measurement curve and the template used in the embodiment of the invention.

A data analyzer embodying the invention will now be described with reference to Figs. 1 to 9. As shown in Fig. 5, the data analyzer 10 is equipped with a microprocessor (CPU) 11, a read only memory (ROM) 12, a random access memory (RAM) 13 and several interface circuits (I/F) 15 to 19 for external devices including a keyboard 21, a mouse (or a joystick) 22, a disk memory device 23 and a display device 24. A measurement apparatus 20, such as a chromatograph or a spectrometer, is connected to the data analyzer 10 via the interface circuit 15.

According to programs stored in the ROM 12 or loaded from the disk memory device 23 into the RAM 13, the CPU 11 of the data analyzer 10 realizes respective elements M1 to M4 (namely a measurement curve generating means M1, a template generating means M2, a moving means M3 and an envelope gen-

erating means M4) of a block diagram of Fig. 4 and performs process steps of a flowchart of Fig. 3. A process of determining the base line of a measurement curve by the data analyzer 10 will now be described referring to the flowchart of Fig. 6.

First, the CPU 11 receives data from the measurement apparatus 20 and stores the data in a measurement data memory area provided in the RAM 13. Instead of receiving data from the measurement apparatus 20, it is possible to retrieve data previously stored in the disk memory device 23. Then the CPU 11 generates a measurement curve C and show it on the display screen 24, as in Fig. 2, by plotting the data against an appropriate parameter (such as time, wavelength, etc.) used in the measurement (step S11). In this phase, the CPU 11 functions as the measurement curve generating means M1.

Regarding the measurement curve C shown on the display screen 24, the operator of the data analyzer 10 gives the CPU 11 a parameter for generating a template T using the keyboard 21 (or the mouse or joystick 22) (step S12). In the present system, as shown in Fig. 2, the chord Tb of the template T is fixed at a preset length, and the arc Ta of the template T is presumed to be parabolic for simplicity. Thus, given the height A of the arc Ta as the parameter, the CPU 11 can generate a fixed shape of template T on the display screen 24. In this phase, the CPU 11 functions as the template generating means M2.

Before finally fixing the shape of the template T, the operator tentatively determines the shape of the template T. Then, moving the template T on the display screen 24 using the keyboard 21 or mouse 22, the operator applies the template T on the part of the measurement curve C having an ostensibly largest curvature. By changing the value of the parameter A (height of the arc Ta) there, the operator determines the final value of the parameter A (or the final shape of the template T) as the smallest value of A with which the arc Ta of the template T does not cross the measurement curve C and contacts it at as many points as possible. It should be stressed here that this adjusting operation need not be so strict. Even if the height A is a little larger or smaller, there is little difference in the finally determined base line B. Therefore the burden of the operator for determining the parameter A is far less than the case for determining the non-apparent parameters in the conventional method.

The geometry of the measurement curve C and the template T is defined as in Fig. 9. The abscissa of the measurement curve C is denoted by the order i (i=0, 1, ..., n) of the sampling points of the measurement (here i corresponds to time, wavelength, etc.), and the height of the measurement curve C (i.e., the value of data) at a sampling point i is denoted as D(i). The height of the base line B is denoted as B(i). The template T is assigned its own coordinate system in which the unit length of the abscissa j is the same as that of i but the origin O is taken at the centre of the chord Tb. The height of the arc Ta from the chord Tb at a point j is denoted as T(j) (j=- m, ..., 0, ..., m). Since the arc Ta is presumed parabolic,

$$T(0) - T(j) = k \cdot j^2$$

where k is a constant. At either end of the chord Tb, i.e., at j=-m or j=m,

$$T(m) = T(-m) = 0,$$

and at the centre O,

$$T(0) = A.$$

Then

$$T(0) - T(m) = A = k \cdot m^2, \text{ or}$$

$k = A/m^2$.

Thus

$$\begin{aligned} T(j) &= T(0) - k \cdot j^2 \\ &= A - (A/m^2) \cdot j^2 \\ &= A \cdot (1 - j^2/m^2). \end{aligned}$$

in the coordinate system (with the origin at the point O) of the template T. If the arc Ta of the template T is presumed to be circular, elliptic, etc., the CPU 11 uses other formulae than those used above, but there is no significant difference in the computing time for recent high-performance microprocessors.

When the final shape of the template T is determined by the operator (step S12), the CPU 11 calculates the values of T(j) (j=-m, ..., 0, ..., m) according to the equation above and stores the values in a template memory area provided in the RAM 13. Then the CPU 11 initializes the values B(i) (i=0, ..., n) of the envelope line (which finally becomes the base line B) stored in memory cells of a base line memory provided in the RAM 13 with the smallest possible value. The smallest possible value is assumed to be 0 in this case. Then the CPU 11 brings the template T to the starting point, i.e., brings the origin O of the template T to the sampling point i=0 (step S13).

After the initialization, the CPU 11 contacts the template T to the measurement curve C (step S15) at the sampling point i. The method of detecting the contact point is detailed later. When the template T is contacted to the measurement curve C, the CPU 11 updates the envelope line of the template T (step S16). The method of updating the envelope line is also detailed later. After updating the envelope line, the CPU 11 moves the template T to the next sampling point i=1 (step S17) and repeats the same process (steps S15-S16) increasing the value of i (step S17) until i=n. The CPU 11 at steps S17 and S15 functions as the moving means M3, and at step S16 functions as the envelope generating means M4. When i reaches n (step S14), the final shape of the envelope line rep-

resents the base line B of the measurement curve C (step S18). After the base line B is determined, the data analyzer 10 processes the measurement data D(i) according to a preset program. For example, the true height of a peak P1, P2 is obtained by subtracting the value of the data by the height of the base line B at the same sampling point, and the area of a peak can be defined by the area surrounded by the measurement curve C and the base line B.

The method of contacting the arc Ta of the template T to the measurement curve C is now explained referring to Fig. 7. Here, for simplicity, the chord Tb of the template T is assumed to be on the zero line Z of the measurement curve C (though they are shown separate in Fig. 9 for better visibility). The CPU 11 moves the template T horizontally and brings the origin O (j=0) to a pertinent sampling point i (step S17). Then the CPU 11 calculates the difference between the ordinate of the measurement curve D(i+j) and that T(j) of the arc Ta of the template T at the same abscissa (step S21). After calculating the distances between the measurement curve C and the arc Ta of the template T at every point of j=-m to j=m, the CPU 11 detects the point jc at which the distance [D(i+j) - T(j)] is the minimum (step S22). The point jc by the coordinate system of template T (or [i+jc] by the coordinate system of the measurement curve C) is the point at which the template T contacts the measurement curve C if the template T is moved vertically by the minimum distance min(D - T) = [D(i + jc) - T(jc)] at the sampling point i (step S23). The template T need not be actually moved vertically on the display screen 24, but it can be performed in the background.

The method of updating the envelope line is then explained referring to Fig. 8. As explained above, the arc Ta of the template T at the sampling point i-1 contacts the measurement curve C at the point [i - 1 + jc1] if the template T is moved vertically by the distance [D(i - 1 + jc1) - T(jc1)]. When the template T is moved horizontally to the next sampling point i, it contacts the measurement curve C at a point [i + jc1] if moved vertically by the distance [D(i + jc2) - T(jc2)]. The arc Ta1 at the sampling point i-1 and the arc Ta2 at the sampling point i do not coincide (because the template T is moved horizontally), and there is a portion of the arc Ta2 that is superior to (above) the arc Ta1. The CPU 11 stores the ordinate T(j) of the portion of the arc Ta2 (that is superior to the arc Ta1) to the memory cell B(i) of the base line memory. The superiority of the arc Ta2 (or the latest arc) can be detected by comparing the value of the ordinate of the arc Ta2(j) = [T(j) + D(i + jc2) - T(jc2)] with the value in the corresponding memory cell B(i+j) (step S31). If [T(j) + D(i + jc2) - T(jc2)] > B(i + j), the data in the memory cell B(i) is updated to the new data Ta2(j) = [T(j) + D(i + jc2) - T(jc2)] (step S32). After the template T is moved from i=0 to t=n, the data in the memory cell B(i) (i=0, 1, ..., n) represent the envelope of the template T thus moved, which is the base line B of the measurement curve C.

Claims

1. A method of determining a base line (B) of a measurement curve (C), the method comprising the steps of:

   preparing (S1) a template (T) having an upwardly convex arc;

   moving (S2), without rotating, the template (T) with the arc of the template always contacting the measurement curve (C); and

   determining (S3) the base line as the envelope of the arc of the template (T).

2. A method according to claim 1, wherein the template moving step (S2) comprises:

   moving the template (T) horizontally under the measurement curve (C);

   calculating (S21), at a given horizontal position of the template (T), the vertical distance between the arc (Ta) of the template and the measurement curve (C) at plural points of the arc of the template;

   detecting (S22) the minimum said vertical distance; and

   moving (S23) the template vertically at the given horizontal position by said minimum vertical distance.

3. A method according to claim 1 or claim 2, wherein the base line determining step (S3) comprises:

   initializing data of the base line by a smallest value;

   judging (S31) whether the arc of the template (T) after movement is superior to the arc before movement at plural points of the arc after movement; and

   updating (S32) data of the base line at the points where the arc after movement is superior to the arc before movement by the data of the arc after movement.

4. A method according to claim 1, claim 2 or claim 3, wherein the arc of the template (T) is parabolic.

5. A method according to claim 1, claim 2 or claim 3, wherein the arc of the template (T) is circular.

6. A method according to claim 1, claim 2 or claim 3, wherein the arc of the template (T) is elliptic.

7. A data processing apparatus for determining a base line (B) of a measurement curve (C), the apparatus comprising:

   measurement curve generating means

(M1);

template generating means (M2) for generating a template (T) having an upwardly convex arc;

moving means (M3) for moving, without rotating, the template (T) so that the arc of the template always contacts the measurement curve (C); and

envelope generating means (M4) for generating an envelope curve of the arc of the template (T) while the template is moved, whereby the envelope is the base line (B) of the measurement curve (C).

8. Apparatus according to claim 7, wherein the moving means (M2) comprises:

horizontal moving means for moving the template (T) horizontally under the measurement curve (C);

distance calculating means for calculating, at a given horizontal position of the template (T), the vertical distance between the arc (Ta) of the template and the measurement curve (C) at plural points of the arc of the template;

minimum detecting means for detecting the minimum said vertical distance; and

vertical moving means for moving the template vertically at the given horizontal position by said minimum vertical distance.

9. Apparatus according to claim 7 or claim 8, wherein the envelope generating means (M4) comprises:

a base line memory composed of a plurality of memory cells for storing data of plural points of the base line (B);

superiority judging means for judging whether the arc of the template (T) after movement by the moving means is superior to the arc before movement at every horizontal point; and

updating means for updating data in the memory cell of the base line memory corresponding to the point where the arc after movement is superior to the arc before movement by the data of the arc after movement.

10. Apparatus according to claim 7, claim 8 or claim 9, wherein the arc of the template (T) is parabolic.

11. Apparatus according to claim 7, claim 8 or claim 9, wherein the arc of the template (T) is circular.

12. Apparatus according to claim 7, claim 8 or claim 9, wherein the arc of the template (T) is elliptic.

Fig. 1

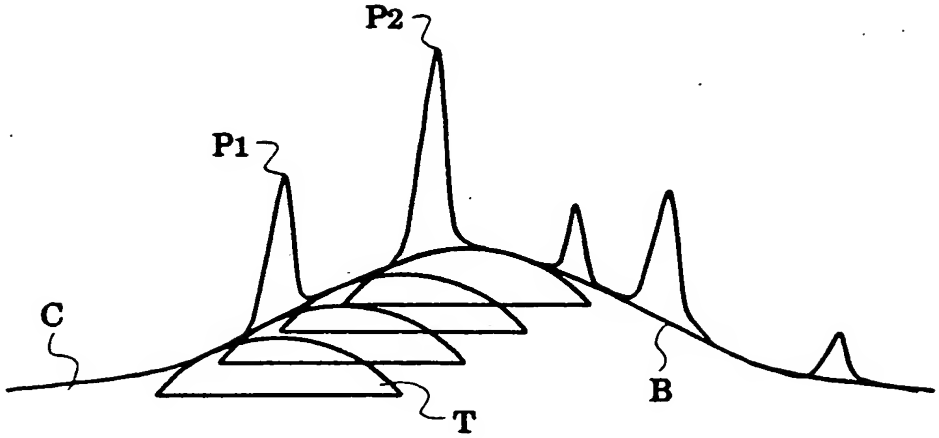

Fig. 2

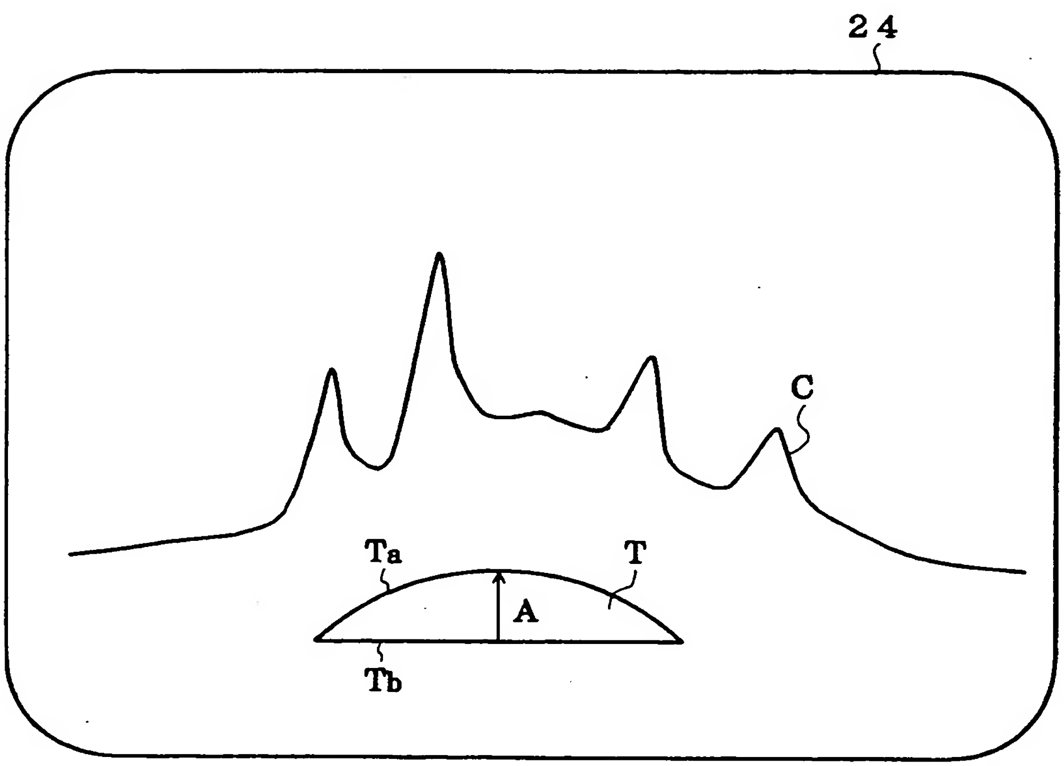

Fig. 3

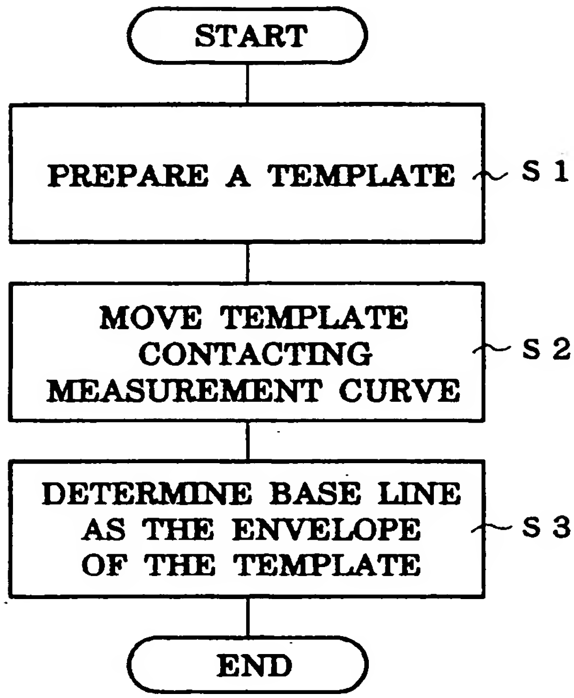
START
PREPARE A TEMPLATE
S 1
MOVE TEMPLATE CONTACTING MEASUREMENT CURVE
S 2
DETERMINE BASE LINE AS THE ENVELOPE OF THE TEMPLATE
S 3
END

Fig. 4

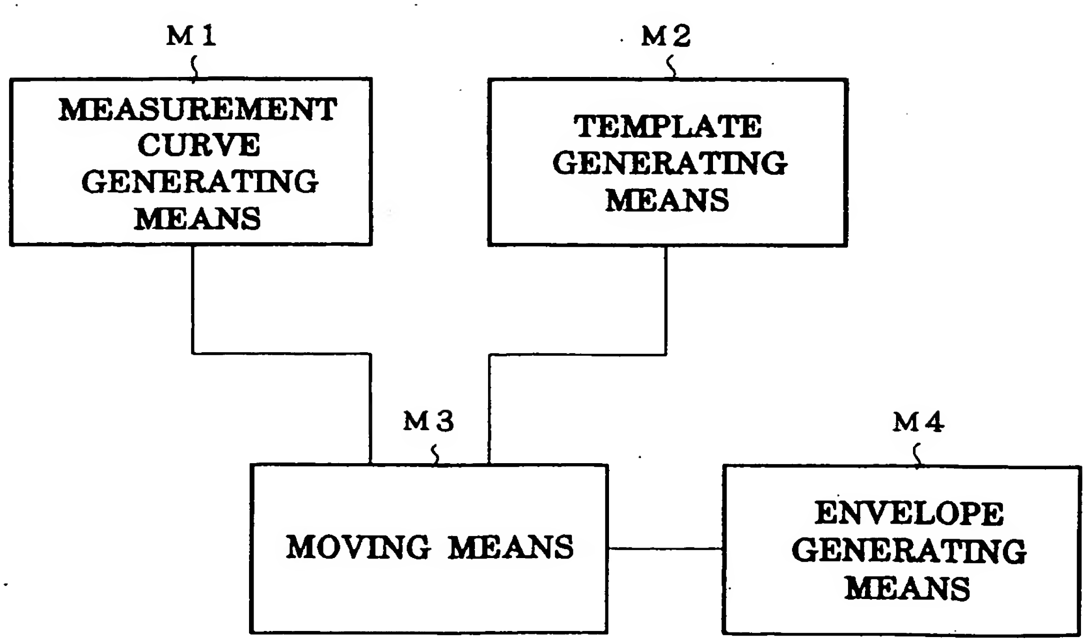
M 1
MEASUREMENT CURVE GENERATING MEANS
M 2
TEMPLATE GENERATING MEANS
M 3
MOVING MEANS
M 4
ENVELOPE GENERATING MEANS

Fig. 5

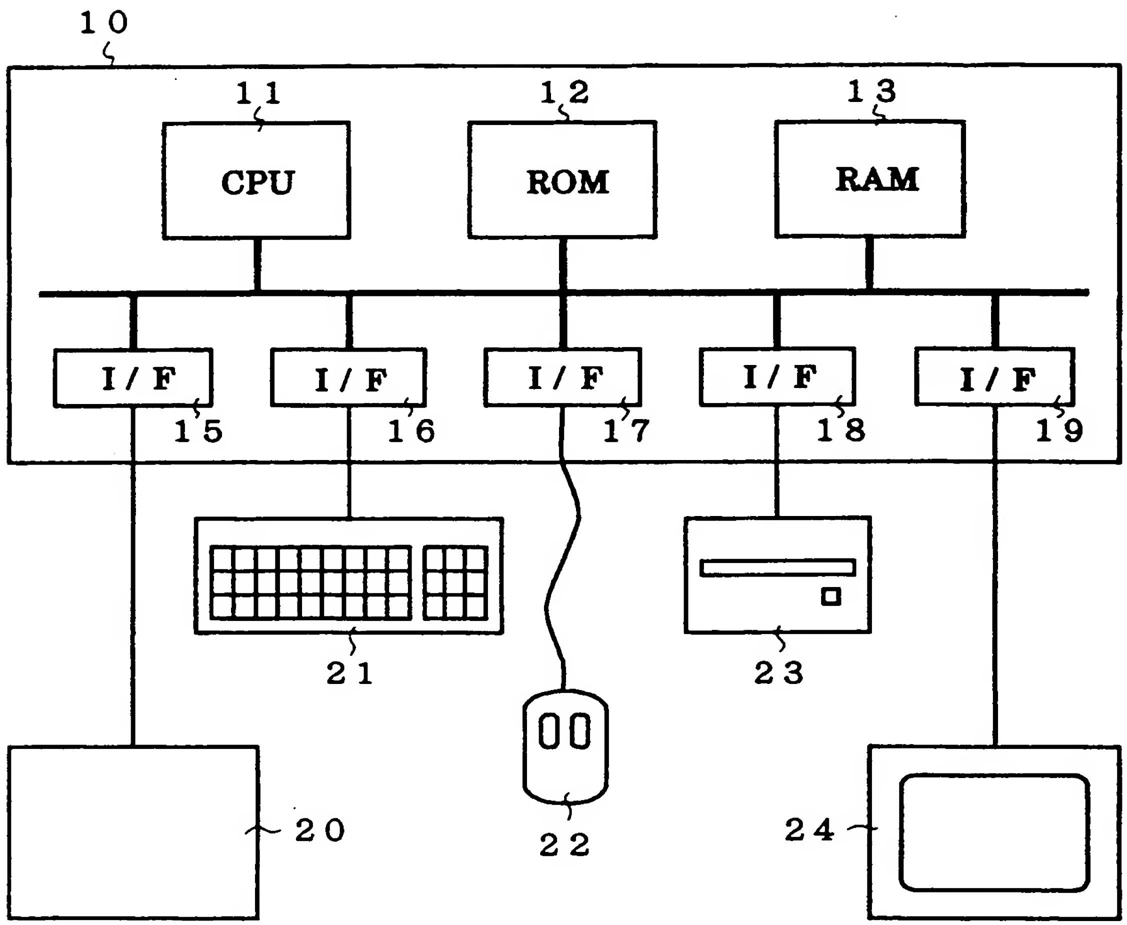

Fig. 6

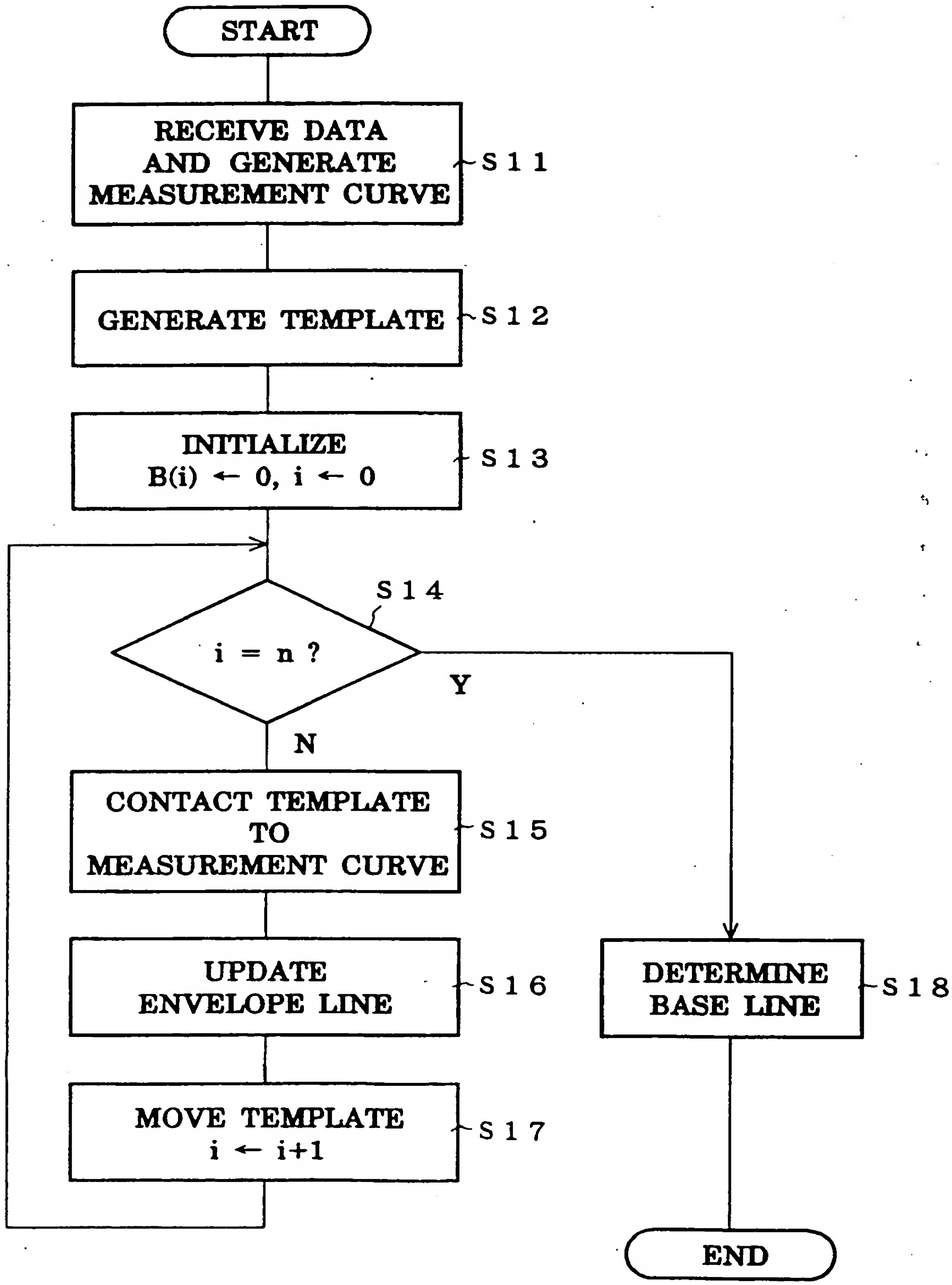
START
RECEIVE DATA AND GENERATE MEASUREMENT CURVE
S11
GENERATE TEMPLATE
S12
INITIALIZE B(i) ← 0, i ← 0
S13
S14
i = n ?
Y
N
CONTACT TEMPLATE TO MEASUREMENT CURVE
S15
UPDATE ENVELOPE LINE
S16
MOVE TEMPLATE i ← i+1
S17
DETERMINE BASE LINE
S18
END

Fig. 7

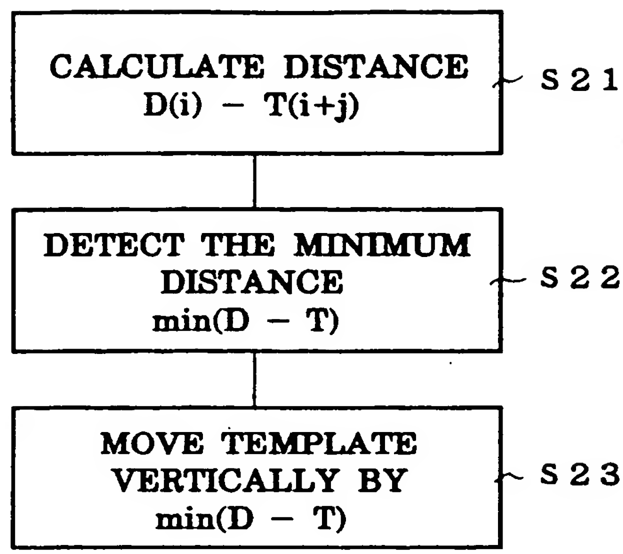
CALCULATE DISTANCE
D(i) – T(i+j)
S 2 1
DETECT THE MINIMUM
DISTANCE
min(D – T)
S 2 2
MOVE TEMPLATE
VERTICALLY BY
min(D – T)
S 2 3

Fig. 8

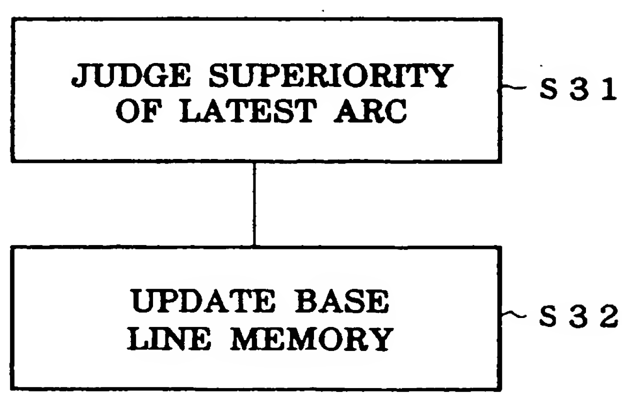
JUDGE SUPERIORITY
OF LATEST ARC
S 3 1
UPDATE BASE
LINE MEMORY
S 3 2

Fig. 9

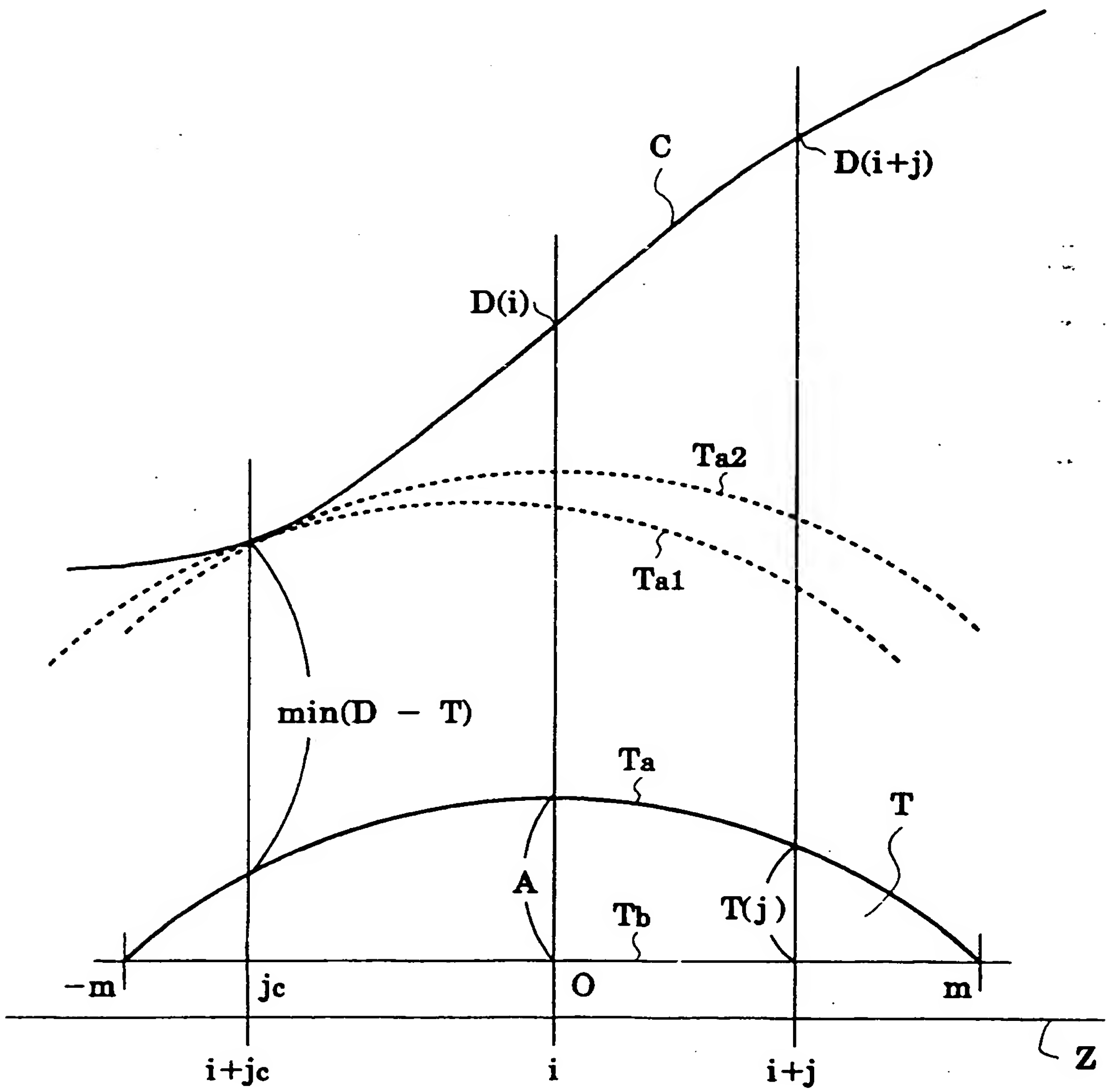

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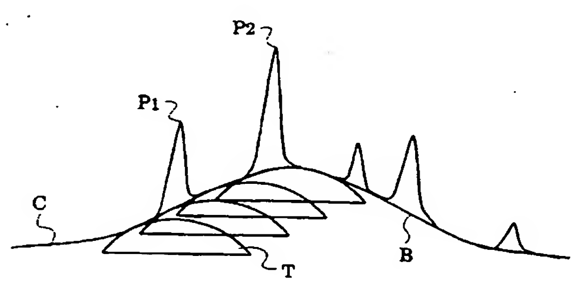
Fig. 1



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EUROPEAN SEARCH REPORT

Application Number
EP 93 30 2152

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	IEEE TRANSACTIONS ON BIO-MEDICAL ENGINEERING vol. 36, no. 2 , February 1989 , NEW YORK US pages 262 - 273 CHEE-HUNG HENRY CHU 'Impulsive Noise Suppression and Background Normalization of Electrocardiogram Signals Using Morphological Operators' * page 263, right column * * page 264, right column, line 16 - page 265, left column, line 14 * * page 268, left column, section VI * ---	1-12	G06F15/20
X	PROCEEDINGS COMPUTERS IN CARDIOLOGY September 1990 , CHICAGO, US pages 313 - 316 D. L. WILSON, C. BERTRAM 'Morphological Enhancement of Coronary Angiograms' * page 313, right column, line 17 - page 314, left column, line 28 * -----	1,2,4-8, 10-12	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 December 1994	Daskalakis, T

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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